

# **Sediment Contamination**

**in Wisconsin's Great Lakes Harbors**

## **Survey Data and Findings**

**By Wisconsin Department of Natural Resources**

**Bureau of Water Regulation and Zoning**

**With support from**

**Wisconsin Department of Administration**

**Coastal Management Program**

**September 1989**

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U.S. DEPARTMENT OF COMMERCE NOAA  
COASTAL SERVICES CENTER  
2234 SOUTH HOEBON AVENUE  
CHARLESTON, SC 29405-2413

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Wisconsin's Great Lakes Harbors:  
Survey Data and Findings**

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**Wisconsin Department of Natural Resources  
Bureau of Water Regulation and Zoning**

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## ABSTRACT

In order to estimate ambient levels of a select number of inorganic (e.g., Cd, Fe, Mn, vol. solids) and organic (e.g., TOC, PCBs, toxaphene, and 2,3,7,8 TCDD/TCDF) toxic compounds in Great Lakes harbor sediment, composite sediment cores were collected at 31 stations in 9 Wisconsin Great Lakes estuaries.

Sampling stations were selected according to two main criteria: Depositional areas subject to dredging and at maximum distances from point source pollution.

The sediment samples collected spanned a wide variety of depositional and composition types with silt being the commonest material. Spatial patchiness within harbors was evident.

## ACKNOWLEDGMENTS

This project was made possible by a grant from the Wisconsin Coastal Management Program (WCMP). The program was established in 1978 to direct attention to the state's 820 miles of Lakes Michigan and Superior coastline. The WCMP analyzes and develops state policy on a wide range of Great Lakes issues, coordinates the many governmental programs that affect the coast and provides grants to stimulate better state and local coastal management. Its overall goal is to preserve, protect and develop the resources of Wisconsin's coastal areas for this and succeeding generations.

The following people were virtually indispensable in the sample collection phase of this project: Mary Ellen Vollbrecht, Ken Johnson, Dick Rost, and Stan Nogalski of Wisconsin Department of Natural Resources (DNR) and Dave Bolgrien and Bob Paddock of the Center for Great Lakes Studies (UW-Milwaukee).

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## TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT . . . . .	i
ACKNOWLEDGMENTS . . . . .	ii
INTRODUCTION . . . . .	1
Purpose of Project . . . . .	1
Selection of Variables for Analysis . . . . .	3
Sampling Site Criteria . . . . .	5
METHODS AND MATERIALS . . . . .	6
Sediment Sampling Equipment . . . . .	6
Sediment Sampling and Handling . . . . .	7
Sediment Analyses and Data Storage . . . . .	8
RESULTS OF SEDIMENT SAMPLING AND ANALYSES . . . . .	10
Field Results and Observation . . . . .	10
Results of Laboratory Analyses . . . . .	11
DISCUSSION AND RECOMMENDATIONS . . . . .	14
Physical Characteristics of Sediment . . . . .	14
Chemical Characteristics of Sediment . . . . .	15
Interpretation of Data . . . . .	15
Recommendations . . . . .	16
LITERATURE CITED . . . . .	19
APPENDIX A: MAPS OF HARBORS SAMPLED . . . . .	A1
APPENDIX B: LOCATIONS OF HARBORS SAMPLED . . . . .	B1
APPENDIX C: LIST OF REVIEWERS . . . . .	C1
APPENDIX D: FIELD OBSERVATIONS OF SEDIMENT . . . . .	D1

## INTRODUCTION

### Purpose of Project

The Bureau of Water Regulation and Zoning of the Wisconsin Department of Natural Resources, under a grant from the state's Coastal Management Program, sampled sediments from estuaries and harbors along the Wisconsin coasts of Lakes Michigan and Superior in the summer of 1989. Sampling sites and water quality variables were selected with four purposes in mind: 1) to provide baseline data (a "snapshot") for certain toxic substances at specific locations where no previous data existed; 2) to refine the protocol for sediment sampling at dredging sites, including the possible reduction in the number of costly analyses (such as those for dioxins and furans) required by the DNR for individual dredging permits; and 3) to identify areas for fish and benthos sampling, for pollution control efforts, and for direction of wildlife and human health studies.

Sampling sites were selected in order to help fulfill the continuing need for the type of ambient sediment data mentioned above, particularly due to a lack of data for certain contaminants at locations believed to have ambient levels.

Recent studies confirm the persistence of some in-place pollutants in the aquatic environment and the importance of focusing on the sediments as the source of significant environmental impacts such as biomagnification (Servos and Muir 1989). Further, bottom foragers (e.g., fathead minnow) bioaccumulate toxins at a much greater rate than surface feeders (Heber and Haffner 1989).

Bioassays with marine harbor sediments (dredged material) containing substantial amounts of both organic and inorganic contaminants have resulted in bioaccumulation of PCBs and cadmium, among others. Acute toxicity tests with the same sediments also illustrate the hydrophobic nature of many contaminants and indicate sensitivity by several infaunal species (including a lethal test) but no sensitivity by epibenthic or water column species (Rogerson et al. 1985).

The Department of Natural Resources has rewritten the Wisconsin Administrative Code pertaining to the regulation of the removal of materials from the beds of waterways. Chapter NR 347, Wis. Adm. Code, clarifies the dredging permit application process and incorporates all pertinent provisions of NR 345, which was repealed. The Wisconsin DNR now makes an initial evaluation of a preliminary application dealing with the proposed dredging activities. Specific sediment sampling and testing are then required by the DNR based on existing data and applying Wisconsin's policy of no significant degradation of the environment beyond that which has already occurred.

In order to aid in adhering to the current policy and due to the lack of workable criteria on the biological effects of toxic sediments, the DNR developed interim criteria for evaluating the potential environmental effects of such sediments. A DNR technical subcommittee decided that the most useful approach currently available to develop such criteria was that of determining background (ambient) levels of contaminants in sediments. Interim criteria were established through comparative analysis of pollutant concentrations found in Lakes Michigan and Superior (Sullivan et al. 1985). Such an approach is necessarily a

compromise between criteria based on sediment samples from a pristine environment or pre-industrial strata, which might be too restrictive, and samples from pollution "hotspots" which might not be restrictive enough.

#### Selection of Parameters for Analysis

Sediment samples taken June-August, 1989 will be analyzed for these water quality parameters:

##### Inorganic constituents-

- Cadmium
- Iron
- Manganese
- Total Volatile Solids

##### Organic Constituents-

- PCBs, total
- Toxaphene
- Dioxin
- Furan
- Total Organic Carbon

##### Physical characteristics-

- Particle Size (percent sand, silt. clay)

These parameters were selected because:

Volatile solids concentration is a good indicator of relative degree of water pollution.

Cadmium is a toxic heavy metal of concern which has been found at levels above EPA limits at a wide variety of locations on Lakes Michigan and Superior, including areas with no obvious sources of pollution.

Iron and manganese have been shown, in marine studies, to have some correlation to the bioavailability of other metals but little freshwater data is available to support the theory (J.E. Rathbun, ASci Corp., Grosse

Ile, MI, personal communication). These two metals are chemically similar, but dissolved manganese was shown to markedly increase in dredged disposal water while dissolved iron decreased as the water moved downstream (Great River Environmental Action Team 1978). The difference could be due to the greater tendency of manganese to dissolve at lower concentration of oxygen (Hem 1959). Both metals are effective scavengers of trace metals and may inhibit dissolution of other metals (Khalid et al. 1977).

Total organic carbon is an important environmental measurement which is highly correlated with bioavailability of various compounds, especially metals. Many new methods for determining bioavailability use a carbon constant.

Toxaphene is a persistent, widely used pesticide which could be expected to be found in a wide variety of depositional locations.

PCBs (polychlorinated biphenyls) are a family of persistent, organic compounds which demonstrate a high biomagnification tendency, are mainly input to the Great Lakes through the air, and could be expected to be found in a wide variety of depositional locations.

Dioxin and furan are persistent organic compounds which biomagnify. Dioxins are extremely toxic and dioxin-contaminated compounds are widely used. They are input to the Great Lakes mainly through the air and can be expected to be found almost anywhere in the environment.

#### Sampling Site Criteria

Sampling sites were selected according to the following two main criteria: minimum number of obvious sources of pollution and likelihood

of (or need for) dredging in the future. And because priorities must also be considered in dredging protocol, extra sampling effort was given to a harbor which has both a minimum amount of toxic pollution and a relatively high need for dredging (i.e., Marinette, which, other than concern about arsenic contamination, has relatively little pollution).

Although the stations selected for sediment sampling for the project have the relatively high levels of nutrients in their sediments typical of urban harbors (with the exception of Port Wing, Ashland, and Two Rivers), past data shows that they have relatively low (under consistent limits of the EPA as well as other guidelines) or nondetectable levels of the contaminants of interest in this study, with the following exceptions:

Cadmium is of concern particularly at Two Rivers and Port Wing where it has exceeded the limits at several sampling stations, but also at Marinette, where the limit was exceeded only in the turning basin. PCBs are of concern in the lower sections of the Root (Racine) and Manitowoc Rivers (although the levels of concern on the Manitowoc River were only slightly over the EPA limit). Total volatile solids has been shown to be relatively high in one area of the lower Root River (Racine) and slightly above the EPA limit in an area of the lower Manitowoc River. However, relatively little data exists on dioxin and chlorinated organic compounds for the harbor sediments of Marinette-Menominee, Two Rivers, and Racine. Metals data for Racine Harbor are also lacking, even though this harbor is considered to be highly polluted based on other data.

Specific, individual sediment sampling stations (See Appendix A and Appendix B) were selected based on literature research (particularly U.S. Army Corps of Engineers and Wisconsin Department of Natural Resources

studies, 1981-83), conversations with other researchers (particularly those involved in work at the proposed study harbors), and on-site sampling. A 1984 Corps of Engineers sediment study of the Fox River in NE Wis. revealed significantly higher PCB levels in sediments near shore than in sediments in or near the channel. There is also a well known tendency of contaminants to concentrate in backwater sediments as opposed to those more exposed to currents.

The basic sampling station selection strategy used in this study was to devise a sampling grid, spread out over known or predicted depositional areas in each harbor or estuary, which maximized distances from known point sources of pollution and emphasized sampling near shore. Control sites were located at upriver and channel locations. A control sample was also collected at a likely pristine site in Rowley Bay.

## METHODS AND MATERIALS

### Sediment Sampling Equipment

Sampling equipment selection was based on personal experience, conversations with other researchers, literature research, equipment availability, project budget, and project goals. Sediment cores were collected where possible with a gravity coring device constructed by the Center for Great Lakes Studies (University of Wisconsin-Milwaukee) and fitted with valves and sleeves made specially for sediment coring by Benthos, Inc. of North Falmouth, MA. The coring device was selected in part because of its capability of taking 4 ft. sediment cores. A 1984 sediment sampling project by the U.S. Army Corps of Engineers on the Fox

River yielded several sediment samples with significant PCB levels at 4-6 ft. depths. Where bottom conditions (e.g., coarse sand, gravel, rocks, wood chips) thwarted the gravity corer, a Petite Ponar dredge was used.

#### Sediment Sampling and Handling

Composite sediment samples were made of 1-4 gravity cores or 1-4 Ponar grabs (at 2 stations where water was wading depth, composite samples were collected with a large spoon to a sediment depth of approximately 5 inches). Each core or dredged grab was measured and visually inspected with appropriate observations on sediment and benthos characteristics logged in a field notebook.

Composite samples were mixed in an aluminum pan with a large stainless steel spoon and subsampled as follows: sample for inorganic analyses in 150 ml plastic "metals" bottle; sample for organic analyses in a glass quart wide-mouthed jar with teflon-lined lid; sample for particle size analysis in pint-size ziplock plastic bag; sample for dioxin-furan analysis (at appropriate stations) in glass quart wide-mouthed jar with teflon-lined lid. Subsamples were taken for dioxin-furan analysis at 9 of the 31 sampling stations. Samples were packed in ice and stored in insulated coolers for up to several hours before being delivered to a walk-in cooler facility prior to being analyzed.

At the time of sampling, most stations were triangulated using a compass, in addition to being located by landmarks, in order to arrive at latitude/longitude readings for STORET system identification. This information will be available in the final report.

### Sediment Analyses and Data Storage

Organic analyses were conducted in the Organic Laboratory of the Wisconsin State Laboratory of (SLOH); inorganic analyses were conducted in the Inorganic Laboratory of SLOH; particle size analyses were conducted at the Soils and Plant Laboratory of the University of Wisconsin-Extension; dioxin-furan analyses were conducted at the EPA Laboratory, Duluth.

Analyses conducted at the Wisconsin SLOH are total (i.e., bulk) sediment analyses. Those conducted at EPA Lab, Duluth are screening tests to determine the presence of 2,3,7,8 TCDD/TCDF.

As sediment data are generated by the Wisconsin SLOH, they are entered, along with the primary station numbers of the sampling stations, into the computerized national water quality database, STORET (See Table 1, next page). STORET is regularly used by all state and federal agencies and researchers. All sediment contaminant levels (See Tables 2, page 12 and 3, page 13) are included in this report which has been sent to many environmental researchers (See Appendix C).

Table 1  
STORET (Primary Station) Numbers  
Corresponding to Sampling Station Numbers

<u>Harbor or Estuary</u>	<u>Sampling Station No.</u>	<u>STORET No. (Primary Station)</u>	<u>Latitude/Longitude</u>
Racine	01	523125	42 44 12/87 46 31
"	02	523126	42 44 00/87 46 59
"	03	523127	42 43 46/87 47 22
"	04	523128	42 43 38/87 47 45
"	05	523129	42 43 57/87 48 52
Ashland	06	023051	46 35 40/90 53 47
"	07	023052	46 36 14/90 53 13
Port Wing	08	043062	46 47 28/91 23 00
Marinette	11	383129	45 05 43/87 35 46
"	12	383130	45 05 46/87 35 45
"	13	383131	45 05 45/87 35 55
"	14	383132	45 05 48/87 36 03
"	16	383134	45 05 55/87 36 32
"	22	383140	45 06 32/87 39 39
Manitowoc	23	363250	44 05 36/87 38 55
"	24	363251	44 05 32/87 39 14
"	25	363252	44 05 52/87 39 45
"	26	363253	44 06 07/87 40 50
Two Rivers	27	363254	44 08 47/87 33 57
"	28	363255	44 08 48/87 33 51
"	29	363256	44 09 11/87 33 50
"	30	363257	44 09 10/87 33 48
"	31	363258	44 09 22/87 33 53
Algoma	32	313050	44 36 29/87 25 55
"	33	313051	44 36 30/87 25 53
"	34	313052	44 36 35/87 26 04
"	35	313053	44 36 32/87 25 56
"	36	313054	44 37 02/87 26 47
Sturgeon Bay	37	153133	44 49 33/87 22 13
"	38	153134	44 48 46/87 20 30
Rowley Bay	39	153135	45 13 50/87 01 50

## RESULTS OF SEDIMENT SAMPLING AND ANALYSES

### Field Results and Observations (See also Appendix D)

The sediment samples in this study were predominated by silts and organic matter, particularly near the surface, which includes the bioturbated top layer of 6-10 cm (2.5 - 4 in.). However, there were some exceptions to this trend.

Clay predominated in the 3 samples furthest downriver on the Manitowoc River. The sample from the outer harbor in Racine had a thick clayey layer of approximately 1 in. on top.

Sand predominated in a couple of samples from the Root River (Racine) above the Soo Line RR bridge. Fine sand predominated in sample no. 03 and coarse sand predominated in sample no. 04 (further upriver).

Harbors with no breakwalls and subject to wave scouring (e.g., Port Wing, Marinette, Two Rivers, Algoma) near the river mouths either yielded samples in those areas which were predominated by sand or were impossible to sample in those areas (in many cases due to coarse sand or rocks) with available equipment. The exception to this was Algoma, where sediment samples collected near the mouth of the Ahnapee River yielded mostly silt, while a sample collected just below the 2nd St. bridge, right descending bank (RDB), was predominantly coarse sand in the top 4 in. Further, unsuccessful attempts were made to collect samples from the 2nd St. bridge down to the marina, left descending bank (LDB).

The East Twin River (Two Rivers) below the turning basin was too scoured to yield sediment with the means available. A similar case existed near the mouth of the Flag River (Port Wing).

The Marinette samples consisted predominantly of fine sand along with wood chips, bark, and rocks. Unsuccessful attempts were made to collect samples along the right descending bank (RDB) from the turning basin to a point approximately 300 ft. above the Ogden St. Bridge.

#### Results of Laboratory Analyses

Results of inorganic analyses, along with particle size data, are in Table 2, page 12. Results of organic analyses are in Table 3, page 13.

[NARRATIVE SUMMARY TO BE ADDED]

Table 2

Results of Inorganic and Particle Size Analyses of Sediments

Inorganic Variables and Particle Size

Sampling Station Numbers	Tot. Vol.	Cadmium	Iron	Manganese	Particle Size Distribution		
	Solids	(Cd)	(Fe)	(Mn)	Sand	Silt	Clay
	<u>%</u>	<u>Tot Dis</u> <u>mg/Kg</u>	<u>Tot Dis</u> <u>mg/Kg</u>	<u>Tot Dis</u> <u>mg/Kg</u>	<u>%</u>	<u>%</u>	<u>%</u>
01 (Racine)							
02 "							
03 "							
04 "							
05 "							
06 (Ashland)							
07 "							
08 (Port Wing)							
11 (Marinette)							
12 "							
13 "							
14 "							
16 "							
22 "							
23 (Manitowoc)							
24 "							
25 "							
26 "							
27 (Two Rivers)							
28 "							
29 "							
30 "							
31 "							
32 (Algoma)							
33 "							
34 "							
35 "							
36 "							
37 (Sturgeon Bay)							
38 "							
39 (Rowley Bay)							

Table 3

Results of Organic Analyses of Sediment

<u>Sampling Station Numbers</u>	<u>Organic Variables</u>			
	<u>TOC mg/Kg</u>	<u>PCBs ng/Kg</u>	<u>Toxaphene ng/Kg</u>	<u>2,3,7,8 TCDD/TCDF ng/Kg</u>
01 (Racine)				
02 "				
03* "				
04 "				
05 "				
06 (Ashland)				
07* "				
08 (Port Wing)				
11*(Marinette)				
12 "				
13* "				
14* "				
16 "				
22 "				
23 (Manitowoc)				
24 "				
25* "				
26 "				
27 (Two Rivers)				
28* "				
29 "				
30 "				
31 "				
32 (Algoma)				
33 "				
34 "				
35* "				
36 "				
37*(Sturgeon Bay)				
38 "				
39 (Rowley Bay)				

\* Samples for dioxin-furan analyses collected at these stations only

## DISCUSSION AND RECOMMENDATIONS

### Physical Characteristics of Sediment

Although the estuary sediments sampled in this study were composed of a wide variety of materials (e.g., rocks, coarse sand, fine sand, silt, clay, organic matter, humus, vegetative matter, and wood fibers) and many of the samples were homogeneous mixtures of several types of material, silt predominated. Estuary sediments tend to grade from the larger and heavier materials (e.g., rocks and coarse sand) to the lighter ones (e.g., silt and clay) from the upper end of an estuary to the lower end; however, it is hard to predict what type of material might be found at any given point along the course of a given river.

The rivers in this study exhibited a range of different depositional patterns. For example, the Marinette harbor estuary sediment was predominantly composed of fine sand, that of Sturgeon Bay, Algoma, and TwoRivers was predominantly silt, and that of Manitowoc was predominantly clay. Sampling effort was not sufficiently concentrated, in most of the study area, to determine degree of patchiness with respect to sediment type. However, at Algoma, core no. 1 of sample no. 34 was significantly different, with 4 in. of coarse sand on top, from core no. 2 and cores of samples 32, 33, and 35 app. 500-1,000 ft. downstream, which were fairly homogeneous mixtures composed mainly of silt or silt and organic matter.

### Chemical Characteristics of Sediment

Due to the possible patchiness of sediment toxicity levels, the results of the chemical analyses for this study should be interpreted with caution, even though an effort was made to collect sediment samples representative of ambient conditions.

### Interpretation of Data

As mentioned earlier, toxic compounds are closely associated with sediments of a particular type which tend to become deposited in somewhat predictable ways. Past studies have shown that many contaminants are hydrophobic, concentrate in the sediment, and typically do not enter the water column upon resuspension but remain adsorbed to sediment particles, the amount of adsorption depending on sediment size, type, and amount of organic matter (Fulk et al. 1975). Thus, environmental effects of resuspension tend to be localized and temporary and most significantly due to suspended solids (e.g., oxygen depletion resulting from increased turbidity) and heavy metals. Heavy metals distribution in Lake Michigan sediments appear to be controlled by their incorporation into the organic matter and clay mineral in finer grained sediments (Cahill 1981) and river pollution tends to reach maximum levels at some point in the downriver section above the river mouth. Several benthic variables (e.g., tubificid worm density and redox potential discontinuity) were found to follow gradients from the central Milwaukee Harbor channel outward (Boyer and Chen 1988; Hausmann 1974).

However, sediment samples can suggest extreme patchiness such as that found in Eagle Harbor, WA, sediments used in lab toxicity tests with an infaunal amphipod (i.e., sediment from one station was acutely toxic

while that from stations within 150 m was not) (Swartz et al. 1989). Some patchiness of sediment contaminant levels may be due to spatial depositional differences resulting from streamflow and lake current scouring effects. There is typically more variation in levels of contaminants in a cross-section of a river than in the direction of stream flow. All of the above considerations illustrate the unique character of any individual estuary, which is due to the unique interplay of physical and biological processes as well as human activities.

The need for more accurate and extensive sediment maps is also apparent. The dynamics of the interaction between polluted sediments and the biota are extremely complex, with effects varying by chemical compound and species of organism, and include the possibility that contaminants not only biomagnify as they shift very rapidly to the food chain but that they become transformed on the way up, possibly to more toxic forms (Ludwig 1989).

#### Recommendations

The best ambient data will probably come from the silty sediment samples. Silty sediment predominates in the harbor estuarine environment and adsorbs toxic compounds more readily than other sediment types. The basic strategy of using a gravity corer with a backup Ponar dredge to sample depositional areas relatively remote from point source pollution seems to have been a sound one for this study. A future study may improve on it by making an accurate sediment map of an ideal estuary for a pilot study (e.g., Two Rivers, Algoma, or Marinette) and concentrate sampling in the areas of silt deposition. Ideally, stations should be sampled at least twice during the year during the year in order to study the effects of biological, physical,

and chemical changes over time. The above estuaries also have good silt depositional areas above the urban, industrial areas. The data generated by this study should fill some holes in the data base for certain contaminants at certain locations and bolster some existing data related to ambient sediment conditions. However, due to the limited number of samples and the possible patchiness of sediment toxicity, data from this study should be interpreted with caution and with other chemical, physical, and biological data. For example, if a piece of data indicates a relatively high level of contamination, it could be an indication of a contaminant lens and, conversely, a piece of data indicating a relatively low level of contamination could reflect an isolated area of nondeposition of pollutants due to a unique condition such as scouring or bioturbation.

The main uses of the data from this study will probably be in formulating future guidelines for specifying predredge sampling protocol and to shape further studies. For example, if toxics such as dioxins and furans are found only at low or nondetectable levels in a given area, such data would support the precluding of predredge sampling there for dioxins and furans. If toxic substances, such as dioxins or PCBs, which bioaccumulate, are found at significant levels in sediment which is also known to make such compounds bioavailable, such sediment would be a good candidate for studies of food chain pathways of such compounds. Also, significant levels of toxic compounds upriver from known point sources of such compounds would indicate an area for further investigation of possible nonpoint pollution sources and abatement efforts. Because sediment is likely the main source of toxic materials to the aquatic biota and food chain and since bioavailability of these contaminants depends on the unique characteristics of any particular sediment,

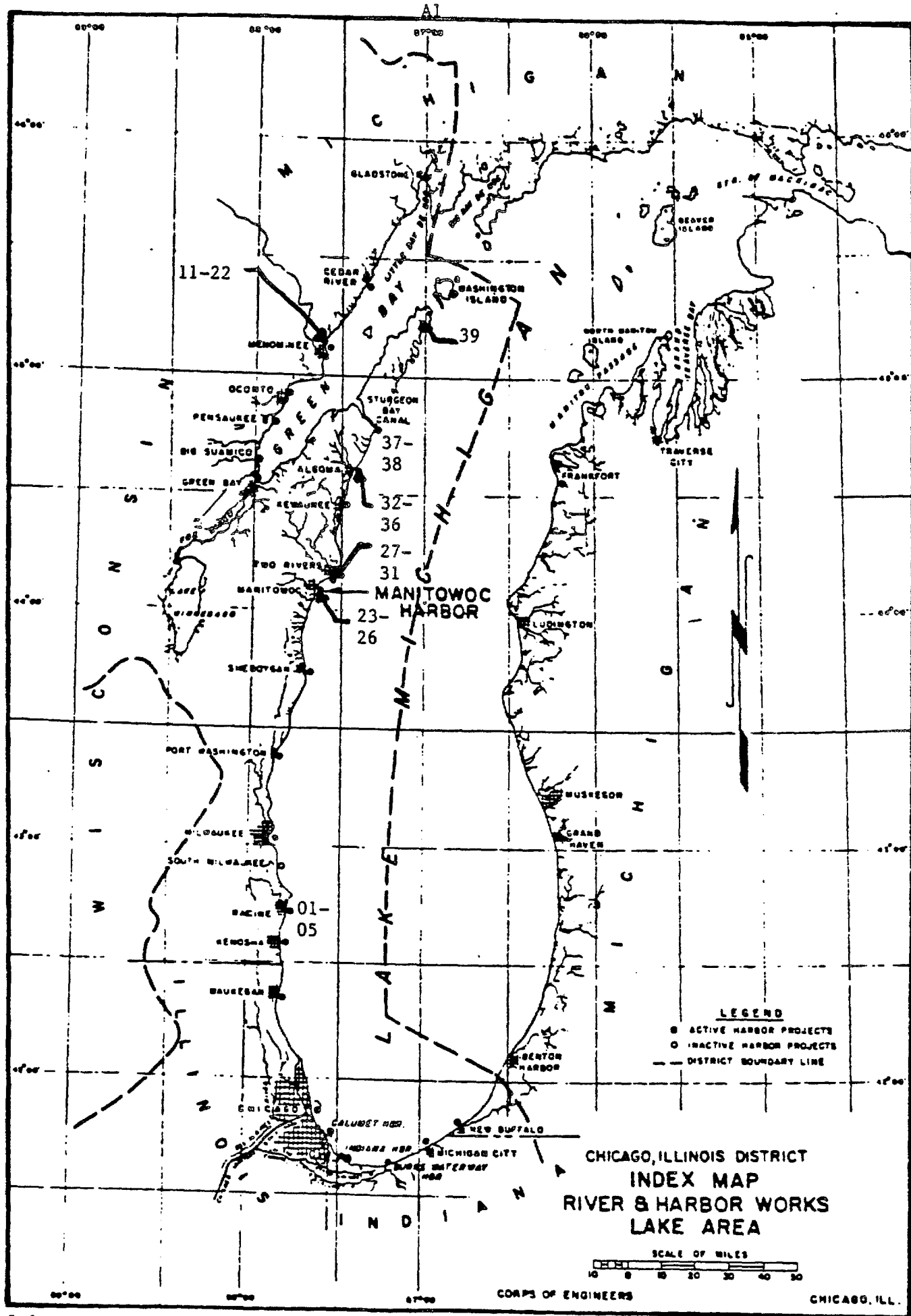
bioassays appear to be the best means available for evaluating the environmental impact of sediment. Further, since toxic compounds are known to become transformed as they work their way up the food chain, further study is needed in tracking particular toxic compounds from benthos to fish and birds.

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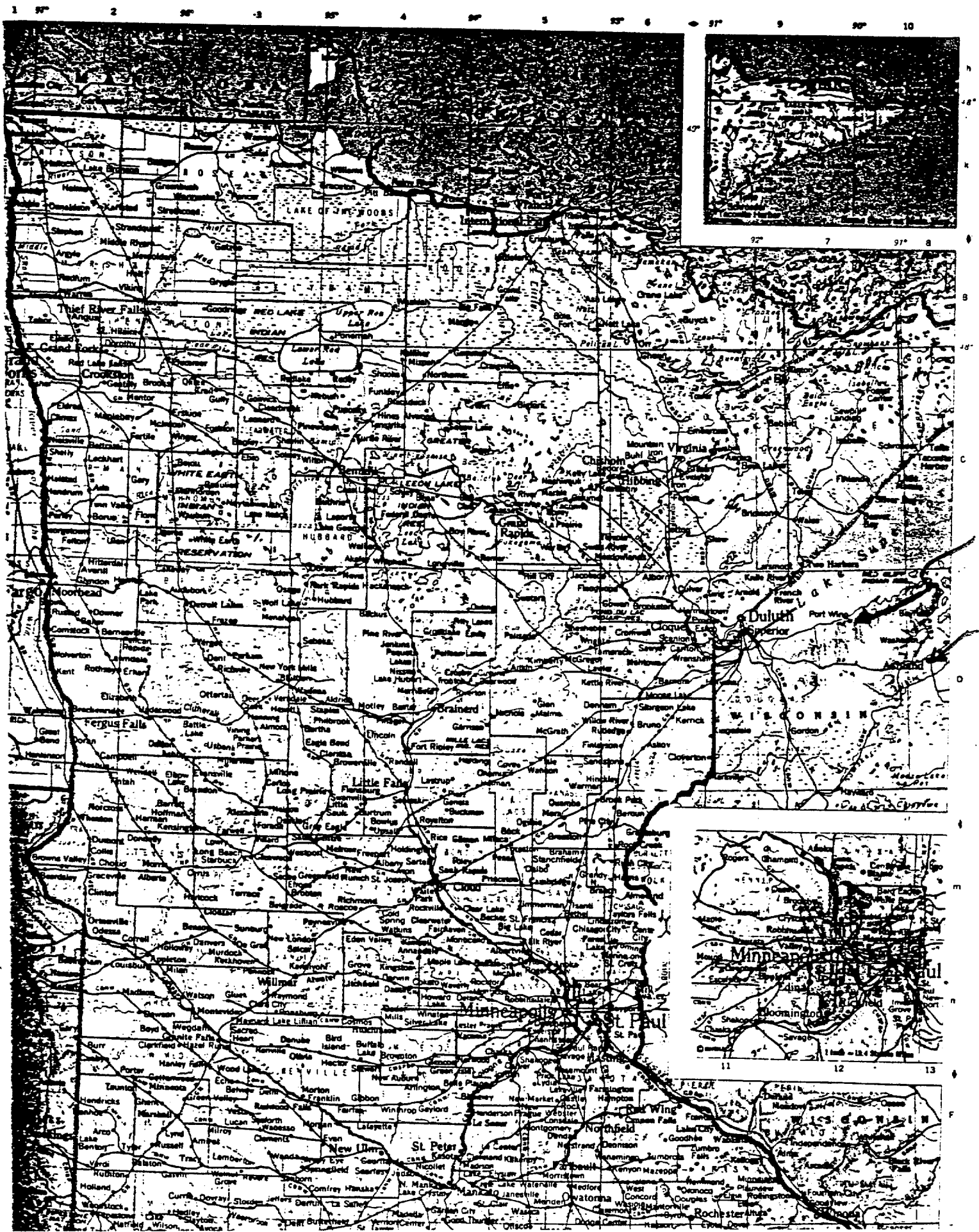
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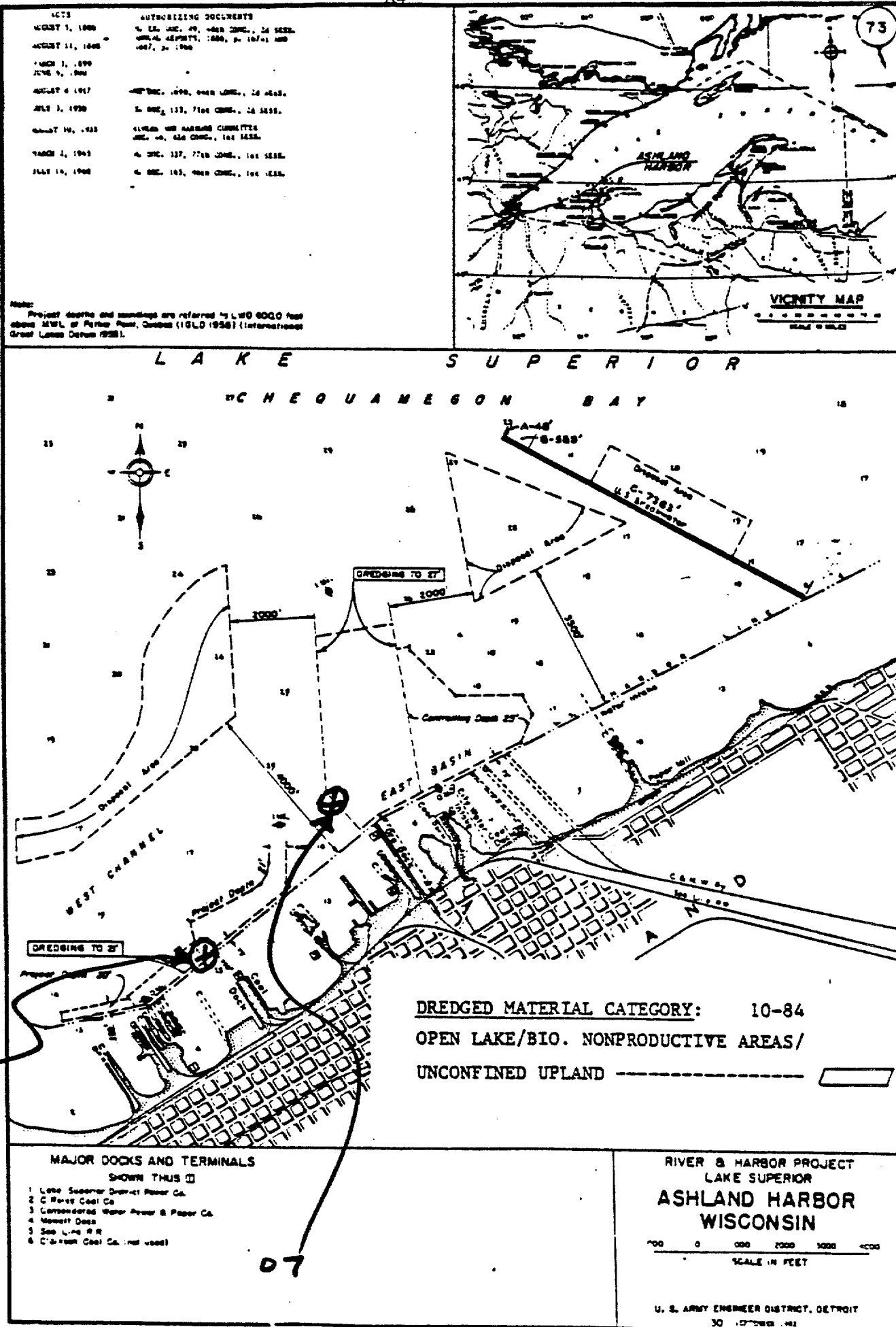
**APPENDIX A**  
**MAPS OF HARBORS SAMPLED**



Lake Michigan Sediment Sampling Stations

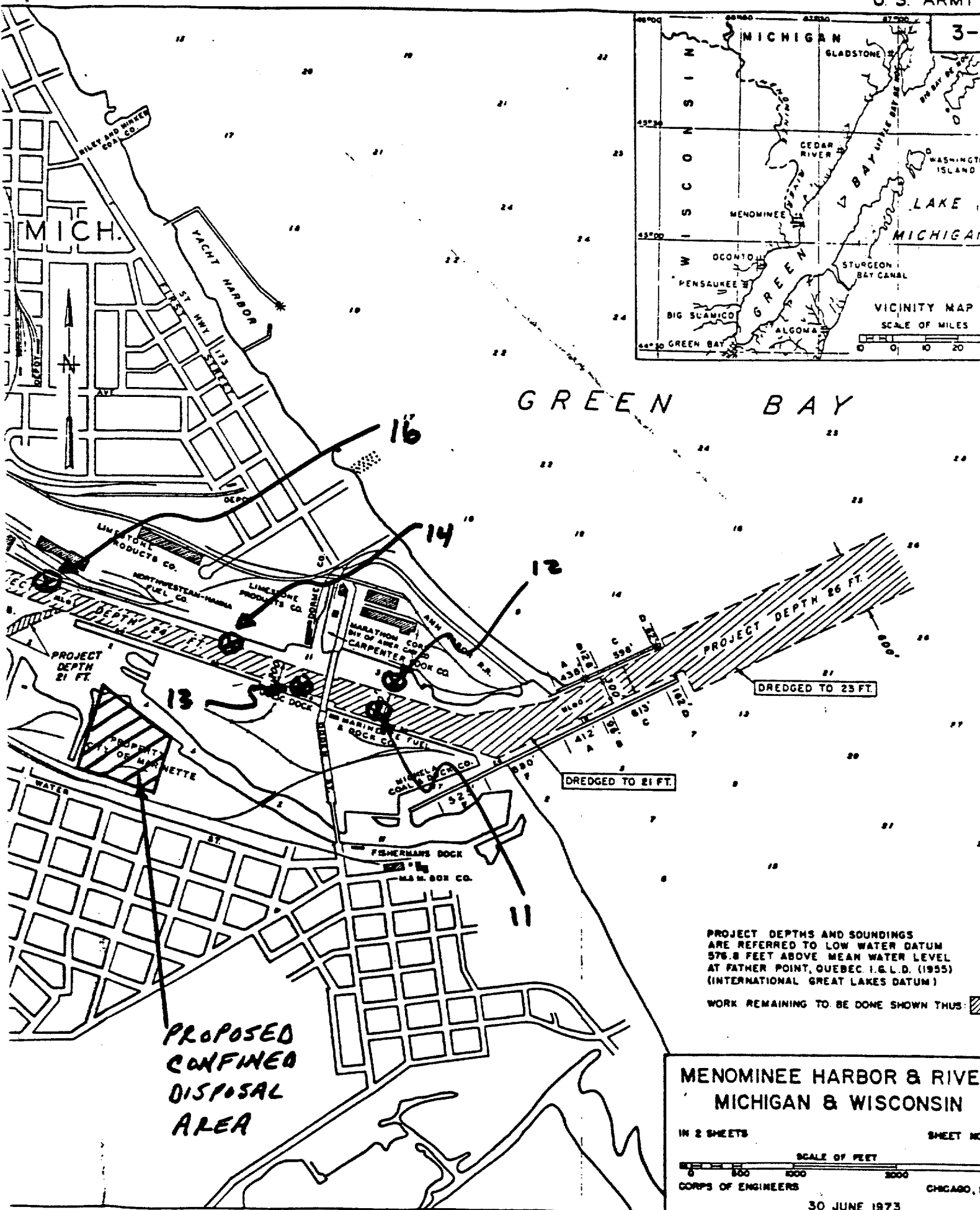




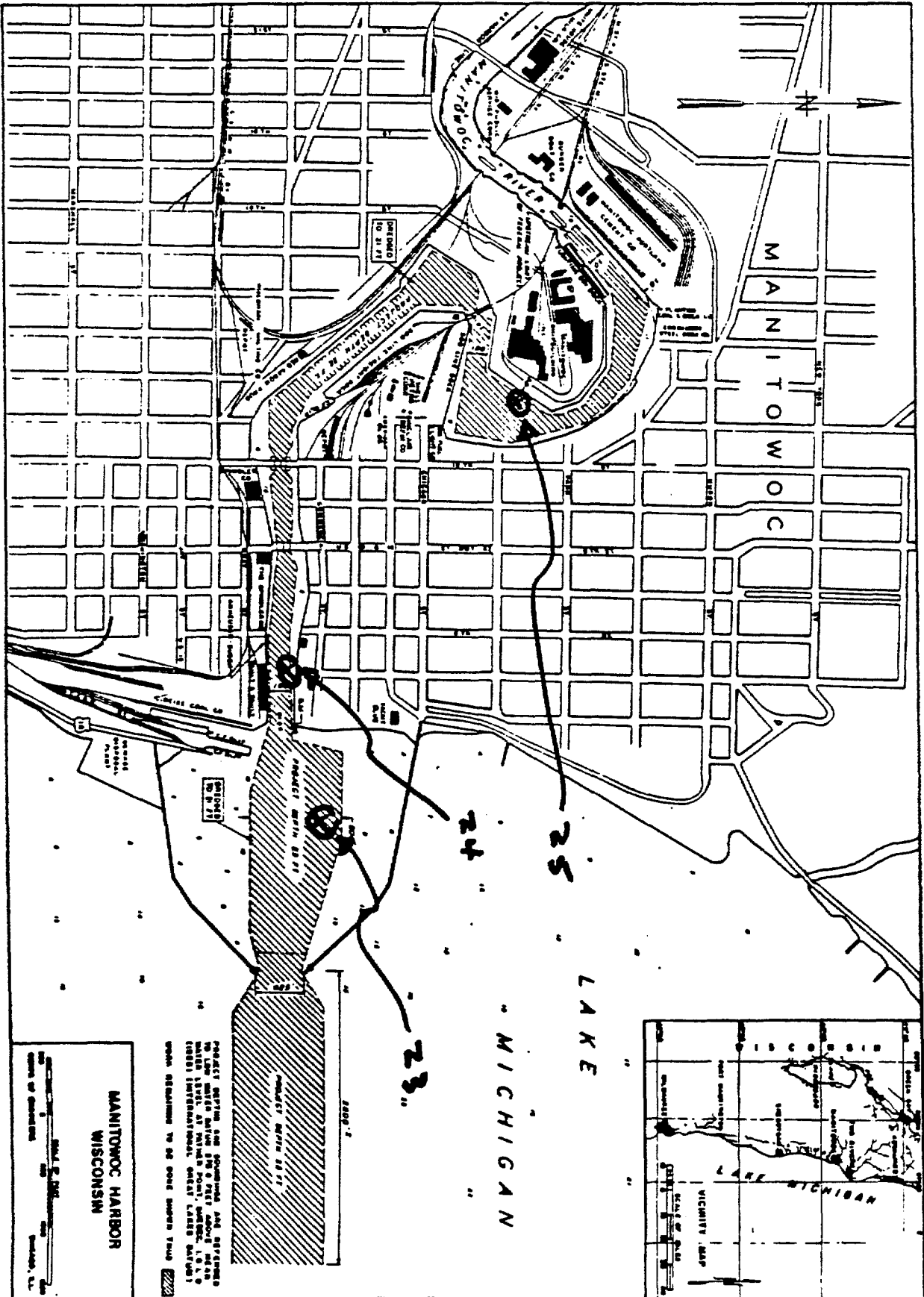


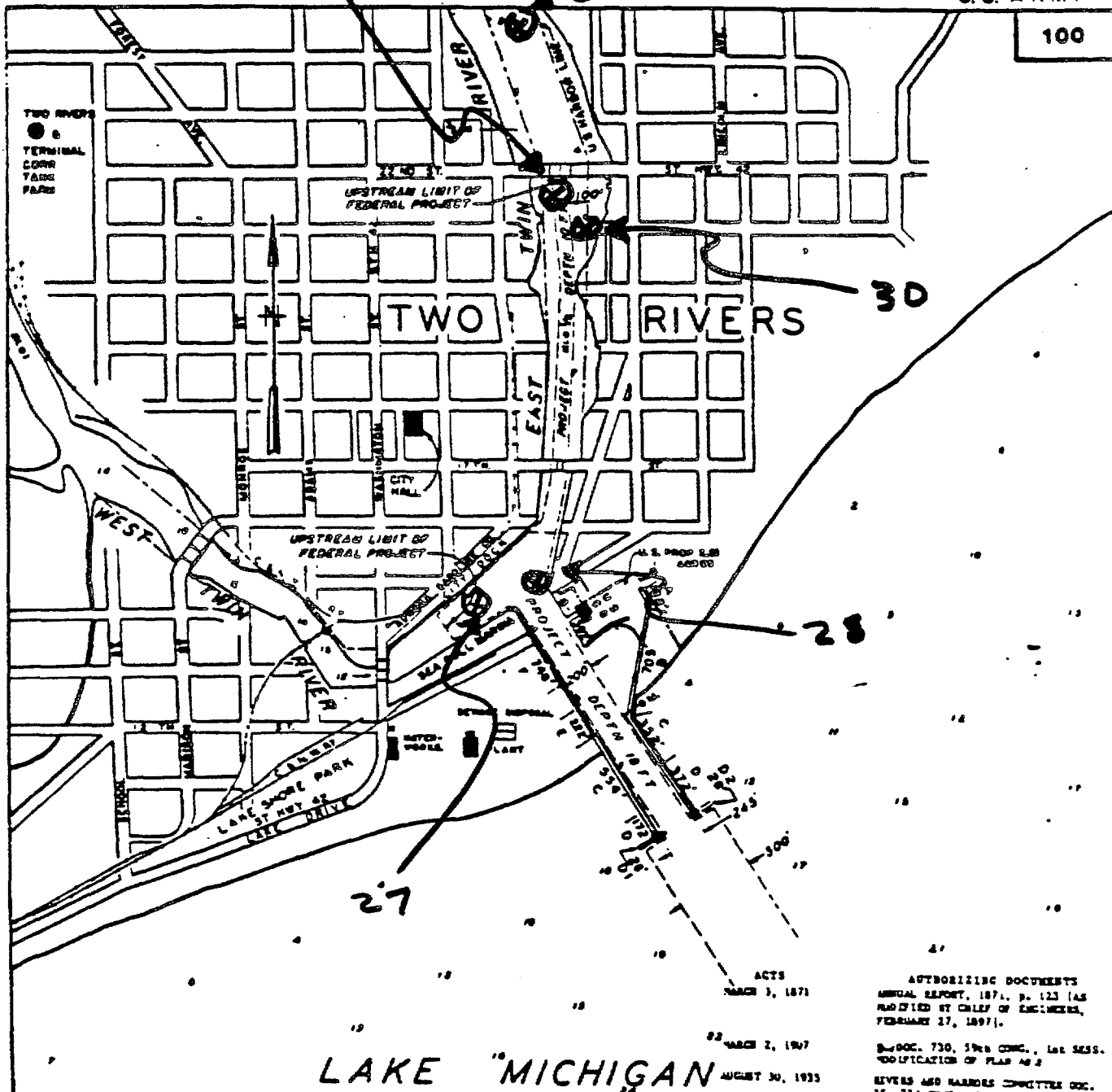
Ashland Harbor Sediment Sampling Stations











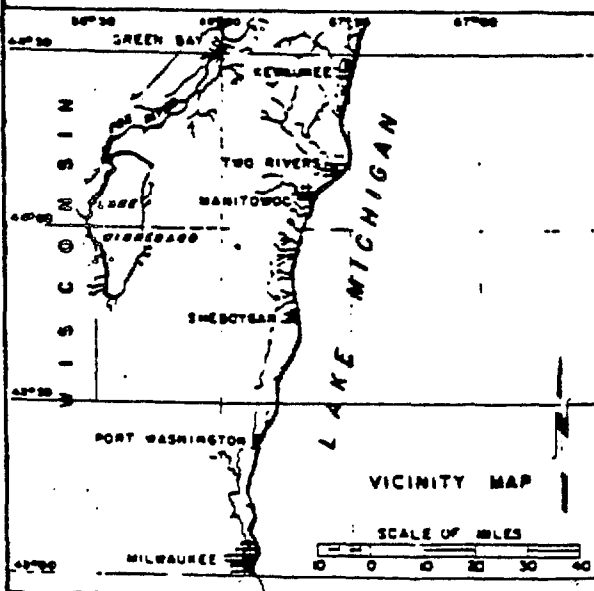
LAKE "MICHIGAN"

ACTS  
MARCH 3, 1871MARCH 2, 1907  
AUGUST 30, 1933

JULY 1, 1934

AUTHORIZING DOCUMENTS  
ANNUAL REPORT, 1871, p. 123 (AS  
MODIFIED BY CHIEF OF ENGINEERS,  
FEBRUARY 27, 1897).S. DOC. 730, 57th CONG., 1st SESS.  
MODIFICATION OF PLAN NO. 2RIVERS AND HARBORS COMMITTEE DOC.  
25, 73rd CONG., 2d SESS.

S. DOC. 362, 84th CONG., 2d SESS.

DREDGED MATERIAL DISPOSAL CATEGORIESA. UNRESTRICTED

VICINITY MAP

SCALE OF MILES

TWO RIVERS HARBOR  
WISCONSIN  
HANCOCK COUNTY

IN 2 SHEETS

SHEET NO. 1

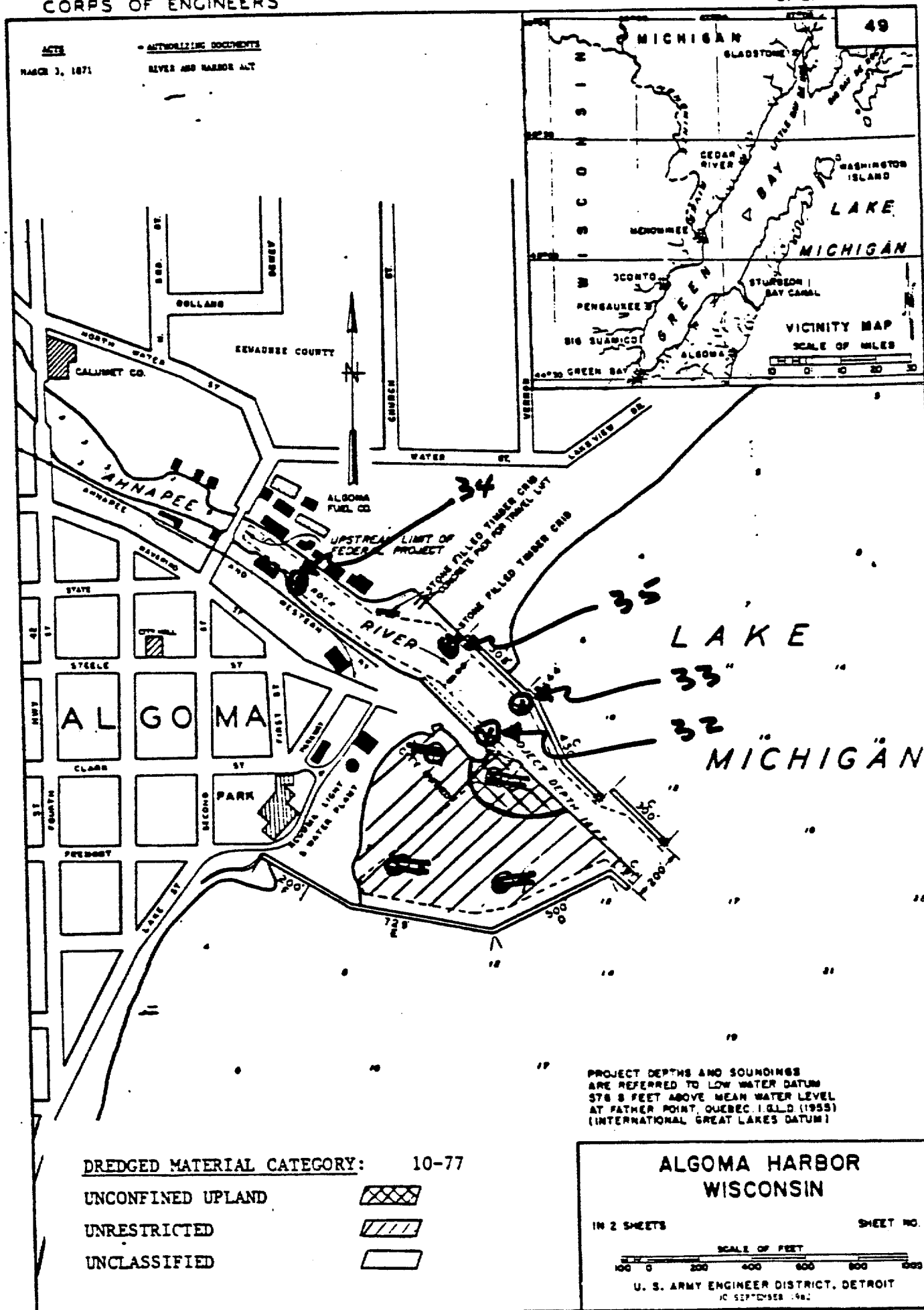
SCALE OF FEET  
0 500 1000 1500 2000U. S. ARMY ENGINEER DISTRICT, DETROIT  
30 SEPTEMBER 1962

ACTS

MARCH 3, 1871

- AUTHORIZING DOCUMENTS

RIVER AND HARBOR ACT





LAKE MICHIGAN

[illegible]

10-10-68

**STURGEON, BAY**

1001  
S.T.

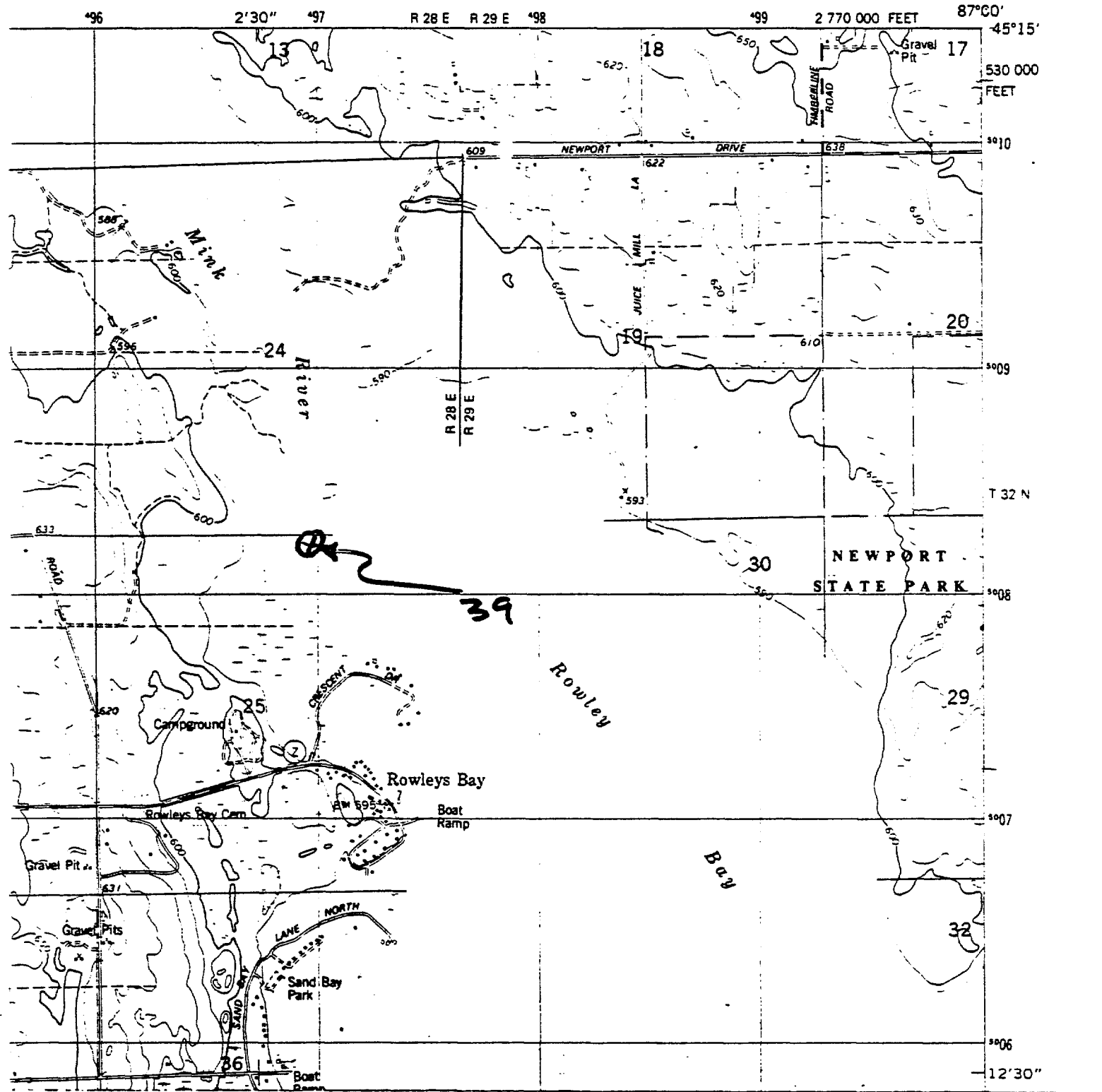
[illegible]

## SISTER BAY QUADRANGLE

WISCONSIN-DOOR CO.

7.5 MINUTE SERIES (TOPOGRAPHIC)

NE/4 SISTER BAY 15' QUADRANGLE

3674 14 SW  
WASHINGTON ISLANDN  
3  
ORY SURVEY

Rowley Bay (Mink River) Sediment Sampling Stations

**APPENDIX B**  
**HARBOR LOCATIONS SAMPLED**

### Racine (Root River)

- Station 01: Outer harbor, app. 25 ft. in from north breakwall.
- Station 02: App. 300 ft. below Hwy. 32 bridge and 75 ft. off right descending bank (RDB).
- Station 03: App. 600 ft. above Soo Line RR bridge (i.e., at Azarian and Sons Co.) and 20 ft. off RDB (i.e., at corner of retaining wall).
- Station 04: App. 200 ft. below C&NW RR bridge and 15 ft. off left descending bank (LDB).
- Station 05: Off middle of Lincoln Park's riverside parking lot and app. 2 ft. off LDB (Station not in map coverage).

### Ashland (Lake Superior)

- Station 06: West channel, app. 1,000 ft. off west dock, C. Reiss Coal Co. Station is in Lake Superior nearshore depositional area subject to dredging.
- Station 07: East basin, app. 800 ft. off Soo Line ore dock and between 2 rad buoys. Station similar to Station 06 but in a separate area subject to dredging.

### Port Wing (Flag River)

- Station 08: Midway along length of turning basin and app. 30 ft. off north wall. Station representative of harbor limited depositional area.

### Marinette (Menominee River)

- Station 11: App. 500 ft. below Ogden Street bridge and 10 ft. off RDB.
- Station 12: App. 500 ft. below Ogden Street bridge and 75 ft. off LDB.
- Station 13: App. 200 ft. above Ogden Street bridge and 75 ft. off RDB.
- Station 14: App. 1,000 ft. above Ogden Street bridge and 50 ft. off LDB (Just below retaining wall).
- Station 16: App. 2,500 ft. above Ogden Street bridge and 30 ft. off LDB (Lower end of boat slip).

### Marinette (Menominee River)

Station 22: Above upper Scott flowage, app. 15 ft. off Indian Mound pt. (LDB).

Sturgeon Bay

Station 37: App. midway between the two bridges in Sturgeon Bay (i.e., midway between the two sets of channel buoys) and app. in mid-channel.

Station 38: App. midway between the two inlets to Sturgeon Bay east of the Bascule bridge and on south edge of navigational channel.

Rowley Bay (Mink River)

Station 39: At mouth of river off LDB and out as far as emergent vegetation.

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**APPENDIX D**  
**FIELD OBSERVATIONS OF SEDIMENT**

HARBOR: RACINE  
16 JUN 89  
Station 01

Time: 1100

Sampling equipment: gravity corer and Petite Ponar  
Number of cores collected: 2  
Number of grabs collected: 3

Core no. 1

Extrusion length: 8.5 in.

Sediment characteristics: homogeneous mixture of sand and silt with mostly silt in upper half and grading down to mostly fine sand in lower portion of core. Several oligochaetes in upper half of core.

Core no. 2

Extrusion length: 3 in.

Sediment characteristics: thick clayey layer on top grading to mixture of silt and fine sand on bottom.

Station 02

Time: 1200

Sampling equipment: gravity corer  
Number of cores collected: 2

Core no. 1

Extrusion length: 16.5 in.

Sediment characteristics: fairly homogeneous mixture of mostly silt and organic matter with some sand. Thin layer of gravel at lower end. Dark color and septic odor.

Core no. 2

Extrusion length: no measured

Sediment characteristics: dark mixture of mostly silt and clay with some organic matter in top portion of core. Grades to mostly fine sand in bottom third of core. Septic odor.

Station 03

Time: 1300

Sampling equipment: gravity corer  
Number of cores collected: 2

Core no. 1

Extrusion length: 3.5 in.

Sediment characteristics: homogeneous mixture of mostly fine sand with some silt.

Core no. 2

Extrusion length: 3 in.

Sediment characteristics: same as core no. 1

Station 04

Time: 1430

Sampling equipment: gravity corer  
Number of cores collected: 1

Core no. 1

Extrusion length: 9 in.

Sediment characteristics: over 90% coarse sand with some silt. Dark color speckled with lighter-colored coarse sand. Slight septic odor.

Station 05

1800

Sampling equipment: sample collected by wading into shallow water and scooping sediment to depth of app. 5 in. with large spoon.

Sediment characteristics: dark brown mixture of mostly silt and sand with some organic mater.

HARBOR: ASHLAND  
29 JUN 89  
Station 06

Time: 1300

Sampling equipment: gravity corer  
Number of cores collected: 4

HARBOR: ASHLAND  
29 JUN 89  
Station 06

Time: 1300

Core no. 1

Extrusion length: 6 in.

Sediment characteristics: homogeneous mixture of silt and medium to fine grained sand. Equal amounts of sand and silt. Tan color.

Core no. 2

Extrusion length: 7.5 in.

Sediment characteristics: similar to core no.1.

Core no. 3

Extrusion length: 4 in.

Sediment characteristics: similar to core no. 1 except to 2.5 in. is siltier.

Core no. 4

Extrusion length: 1 in.

Sediment characteristics: top 5 in. grades from mixture of sand and silt which is mostly sand to one which is mostly silt. Layer from 5-7.5 in. is mostly silt. Bottom 3.5 in. is all sand.

Station 07

Time: 1400

Sampling equipment: gravity corer  
Number of cores collected: 4

Core no. 1

Extrusion length: 9.5 in.

Sediment characteristics: top 5 in. is tan-colored and mostly silt. Layer from 5-7 in. is lighter in color and sandier. Bottom 2.5 in. is darker (coffee color) mixture of mostly silt with some clay and organic matter.

HARBOR: ASHLAND  
29 JUN 89  
Station 06

Time: 1300

Core no. 2

Extrusion length: 9.5 in.

Sediment characteristics: similar to core no. 1 but is tan-colored and appears more homogeneous.

Core no. 3

Extrusion length: 11 in.

Sediment characteristics: upper half of core grades from mostly silt (with some clay and organic matter and a slight amount of bark and vegetative matter) to mostly sand. Bottom half is mostly fine sand.

Core no. 4

Extrusion length: 12 in.

Sediment characteristics: similar to core no. 3 except that there is less vegetative and organic matter.

HARBOR: PORT WING  
30 JUN 89  
Station 08

Time: 0845

Sampling equipment: gravity corer  
Number of cores collected: 4

Core no. 1

Extrusion length: 10 in.

Sediment characteristics: fairly homogeneous mixture of sand and silt; some organic matter in upper third of core; tan color.

Core no. 2

Extrusion length: 9 in.

Sediment characteristics: upper half: mixture of sand, silt, and organic matter. Lower half: fine sand and silt; increase in organic matter.

HARBOR: PORT WING  
30 JUN 89

Station 08

Time: 0845

Core no. 3

Extrusion length: 10 in.

Sediment characteristics: homogeneous mixture of fine and medium grain sand, silt, and organic matter. Middle 3 in. layer of fine sand.

Core no. 4

Extrusion length: 12 in.

Sediment characteristics: similar to core no. 1.

HARBOR: MARINETTE  
1 AUG 89  
Station 11

Time: 1900

Sampling equipment: Petite Ponar  
Number of grab samples: 3

Sediment characteristics: all 3 grabs are mixture of sand, wood chips, and bark.

Station 12

Time: 1800

Sampling equipment: gravity corer  
Number of cores collected: 2

Core no. 1

Extrusion length: 7 in.

Sediment characteristics: homogeneous mixture of mostly sand and some silt, but top 4 in. is dark in color and bottom 3 in. is brown.

Core no. 2

Extrusion length: 9 in.

Sediment characteristics: mostly fine sand with a 1-2 in. oily layer on bottom.

HARBOR: MARINETTE  
1 AUG 89  
Station 13

Time: 94

Sampling equipment: Petite Ponar  
Number of grab samples: 3

Sediment characteristics: all 3 grab samples mostly fine sand with a lot of wood chips and bark.

Station 14

Time: 1300

Sampling equipment: Petite Ponar  
Number of grab samples: 4

Sediment characteristics: all 4 grab samples mostly fine sand with rocks, wood chips, and some organic matter.

Station 16

Time: 1145

Sampling equipment: Petite Ponar  
Number of grab samples: 4

Grab no. 1

Sediment characteristics: dark, homogeneous mixture of 50% sand and 50% silt; some organic matter and oligochaetes present.

Grab nos. 2-4

Sediment characteristics: similar to grab no. 1 plus rocks, bark, wood chips.

Station 22

Time: 1200

Sampling equipment: gravity corer  
Number of cores collected: 4

Core no. 1

Extrusion length: 3 in.

Sediment characteristics: fine sand and unconsolidated silt with wood chips and a slight amount of pea gravel.

HARBOR: MARINETTE  
1 AUG 89  
Station 22

Time: 1200

Core no. 2

Extrusion length: 6 in.

Sediment characteristics: 2 in. silt and fine sand overlying 4 in. fine sand; stonefly larvae near top of core.

Core no. 3

Extrusion length: 2 in.

Sediment characteristics: 1 in. silt overlying 1 in. sand; stonefly larvae on top of core.

Core no. 4: not examined.

HARBOR: MANITOWOC  
8 AUG 89  
Station 23

Time: 1400

Sampling equipment: gravity corer  
Number of cores collected: 2

Core no. 1

Extrusion length: 14.5 in.

Sediment characteristics: fairly homogeneous mixture of mostly clay with some sand and vegetative matter.

Core no. 2

Extrusion length: 16 in.

Sediment characteristics: same as core no. 1 except for a bottom layer of 3 in. composed of more vegetative matter.

Station 24

Time: 1415

Sampling equipment: gravity corer  
Number of cores collected: 2

HARBOR: MANITOWOC  
8 AUG 89  
Station 24

Time: 1415

Core no. 1

Extrusion length: 10 in.

Sediment characteristics: top half of core mostly clay with some sand and organic matter. Bottom half grades to mostly sand with some clay and an increase in organic matter.

Core no. 2

Extrusion length: 15.5 in.

Sediment characteristics: same as core no. 1.

Station 25

Time: 1445

Sampling equipment: gravity corer  
Number of cores collected: 2

Core no. 1

Extrusion length: 20 in.

Sediment characteristics: top 9 in. is dark, loose, silty organic material and clay. Bottom 11 in. is similar except that it is more consolidated and clayey. Core is very homogeneous and mostly clay.

Core no. 2

Extrusion length: 19 in.

Sediment characteristics: same as core no. 1.

Station 26

Time: 1645

Sampling equipment: gravity corer  
Number of cores collected: 2

Core no. 1

Extrusion length: 10.5 in.

Sediment characteristics: mostly silt with some clay, sand, and organic matter in top half of core grading to a greater % clay and sand toward bottom.

HARBOR: MANITOWOC  
8 AUG 89  
Station 26

Time: 1645

Core no. 2

Extrusion length: 12 in.

Sediment characteristics: similar to core no. 1 plus some pea gravel in top half of core and a few snail and clam shells at app. 4 in. level in core.

HARBOR: TWO RIVERS  
9 AUG 89  
Station 27

Time: 0915

Sampling equipment: gravity corer  
Number of cores collected: 2

Core no. 1

Extrusion length: 8 in.

Sediment characteristics: upper two-thirds of core is dark mixture of mostly silt with some sand and a little organic matter. Lower third of core consists of more clay and organic matter. Slight septic odor.

Core no. 2

Extrusion length: 8 in.

Sediment characteristics: similar to core no. 1.

Station 28

Sampling equipment: gravity corer  
Number of cores collected: 2

Core no. 1

Extrusion length: 11.5 in.

Sediment characteristics: upper half of core consists of mostly silt and clay with some sand. Lower half is similar, but with an increase in % sand and presence of some organic matter. Core is a dark color and has a slight septic odor.

HARBOR: TWO RIVERS  
9 AUG 89  
Station 28

Core no. 2

Extrusion length: 18 in.

Sediment characteristics: core not examined.

Station 29

Time: 1000

Sampling equipment: gravity corer  
Number of cores collected: 2

Core no. 1

Extrusion length: 8 in.

Sediment characteristics: dark mixture of sand, silt, and clay with % clay increasing greatly in bottom 2 in. Core also contains some organic matter and a few small clam shells, pieces of tree branches, and wood chips.

Core no. 2

Extrusion length: 18 in.

Sediment characteristics: similar to core no. 1 except that clay layer begins 2-3 in. from top of core and no clam shells are evident.

Station 30

Time: 1015

Sampling equipment: gravity corer  
Number of cores collected: 2

Core no. 1

Extrusion length: 14 in.

Sediment characteristics: mixture of sand, silt, clay, and organic matter, with the organic matter increasing greatly in bottom few inches. Wood chips also present in bottom few inches.

Core no. 2

Extrusion length: 17.5 in.

Sediment characteristics: similar to core no. 1 except for small amount of oil or grease and parts of crayfish at mid-core with strong odor of decay.

HARBOR: TWO RIVERS  
9 AUG 89  
Station 31

Time: 1130

Sampling equipment: gravity corer  
Number of cores collected: 3

Core no. 1

Extrusion length: 3.5 in.

Sediment characteristics: mostly silt, clay,  
and organic matter with a little sand.

Core no. 2

Extrusion length: 6.5 in.

Sediment characteristics: similar to core no.  
1 except for greater % clay (and presence of  
wood chips) deeper in core.

Core no. 3

Extrusion length: 11 in.

Sediment characteristics: similar to core no.  
2 except consistency is more consolidated and  
hardpacked (humus-like).

HARBOR: ALGOMA  
9 AUG 89  
Station 32

Time: 1345

Sampling equipment: gravity corer  
Number of cores collected: 2

Core no. 1

Extrusion length: 12 in.

Sediment characteristics: top layer of 7.5 in.  
consists of mostly dark silt with some sand and  
organic matter. Middle 3 in. layer of very light-  
colored, fine sand. Bottom 1.5 in. layer of  
mostly gray-colored sand and some organic matter.

HARBOR: ALGOMA  
9 AUG 89  
Station 32

Time: 1345

Core no. 2

Extrusion length: 10.5 in.

Sediment characteristics: similar to core no.1.

Station 33

Time: 1400

Sampling equipment: gravity corer  
Number of cores collected: 2

Core no. 1

Extrusion length: 13 in.

Sediment characteristics: consists mostly of dark mixture of silt and organic matter with some sand. Percent sand increases with depth. Thin layer of light-colored, fine sand at mid-core and stone near bottom of core.

Core no. 2

Extrusion length: 16 in.

Sediment characteristics: similar to core no. 1.

Station 34

Sampling equipment: gravity corer  
Number of cores collected: 2

Core no. 1

Extrusion length: 8.5 in.

Sediment characteristics: upper half of core mostly coarse sand with some silt. Lower half of core becomes like humus with a lot of organic matter and silt and a little sand. A few pieces of twigs at mid-core.

Core no. 2

Extrusion length: 3.5 in.

Sediment characteristics: top inch consists of dark mixture of mostly silt with some sand. Bottom 2.5 in. is mostly gray, fine sand.

HARBOR: ALGOMA  
9 AUG 89  
Station 35

Sampling equipment: gravity corer  
Number of cores collected: 3

Core no. 1

Extrusion length: 9 in.

Sediment characteristics: top 7 in. consists of dark mixture of silt, sand, and organic matter. Bottom 2 in. consists of greater percentage of sand.

Core no. 2

Extrusion length: 13 in.

Sediment characteristics: top 9 in. consists of dark mixture of silt, sand, and organic matter. Bottom 4 in. consists of a greater % of sand. Top and bottom layers separated by thin band of light, very fine sand.

Core no. 3

Extrusion length: 11.5 in.

Sediment characteristics: top 6 in. consists of dark mixture of silt, sand, and organic matter. Bottom 5.5 in. is dark mixture of silt and organic matter with a humus-like consistency.

Station 36

Time: 1615

Sampling equipment: gravity corer  
Number of cores collected: 2

Core no. 1

Extrusion length: 19 in.

Sediment characteristics: very homogeneous, dark mixture of mostly silt and organic matter with percent organic matter increasing with depth and giving sediment a humus-like consistency.

HARBOR: ALGOMA  
9 AUG 89  
Station 36

Time: 1615

Core no. 2

Extrusion length: 23 in.

Sediment characteristics: similar to core no.  
1. Bottom 2-3 in. have reddish-brown color.

HARBOR: STURGEON BAY  
10 AUG 89  
Station 37

Time: 1530

Sampling equipment: gravity corer  
Number of cores collected: 3

Core no. 1

Extrusion length: 14 in.

Sediment characteristics: very homogeneous,  
dark mixture of mostly silt with some sand, clay,  
and organic matter. Amount of clay increases  
in bottom few inches of core. Small rock at  
bottom of core.

Core no. 2

Extrusion length: 15 in.

Sediment characteristics: similar to core no.  
1, but more clay present and almost no organic  
matter apparent. Thin streaks of light-colored  
sand at mid-core.

Core no. 3

Extrusion length: 14 in.

Sediment characteristics: similar to cores 1  
and 2. A very small clam and snail shells in  
lower half of core. Small rock at bottom of  
core.

Station 38

Time: 1745

Sampling equipment: gravity corer  
Number of cores collected: 2

Station 38

Time: 1745

Core no. 1

Extrusion length: 13 in.

Sediment characteristics: consists mostly of dark gray mixture of silt and clay with some sand and organic matter. Core is fairly homogeneous but percent clay increases greatly with depth.

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DATE DUE

Station 39

**in.**

similar to core no.1.

Time: 1815

ple was collected by  
r mouth and scooping  
in. with large spoon.

homogeneous, gray  
with some fine sand and

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